

# **Investigation of Near-Axial Interference Effects in Long Range Acoustic Propagation in the Ocean**

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## **INTRODUCTION**

Since the end of the first year of funding of the St. Petersburg State Marine Technical University (SMTU) effort is approaching and the Atlantic Oceanographic and Meteorological Laboratory (AOML) effort is in the middle of its second year, it seems appropriate to review the significant aspects of the project. The work at the two institutions did not start at the same time because of the unavoidable delays in arranging for the transfer of funds to St. Petersburg.

## **LONG-TERM GOALS**

### **Tasks and Milestones**

The major tasks and milestones listed in the original proposal dated November 2, 2001, are:

#### Major tasks

- (1) Provide an English-language summary of the work done by Buldyrev and co-workers.
- (2) Provide a summary of the experimental, theoretical, and numerical results obtained to date concerning the axial crescendo and relate those results to Buldyrev's work.
- (3) Construct a representation for the axial wave based on a range-independent sound speed for comparison with WKBJ and normal mode solutions.
- (4) Construct a representation for the axial wave based on a range-dependent sound speed field.
- (5) Undertake time-of-arrival simulations.

#### Milestone plan

- Year 1** 1Q Acquire Pentium III PC, printer, and software.  
1Q Complete the translation of all relevant research articles.

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- 1Q Begin the analysis of the range-independent problem.
- 2Q Hold project workshop in Miami.
- 3Q Attend Pittsburgh Acoust. Soc. Am. meeting.
- 4Q Complete review article of the work done by Buldyrev and co-workers.
- 4Q Complete the analysis of the range-independent problem.

- Year 2**
- 1Q Develop the ocean model for the range-dependent problem.
  - 1Q Begin numerical calculations for the range-dependent problem.
  - 2Q Hold project workshop in Miami.
  - 3Q Attend 6th Int. Conference on Theoretical & Computational Acoustics, Hawaii.
  - 4Q Complete the analysis of the range-dependent problem.

### **Plans for the Fourth Quarter of the First Year**

1. Study of the axial wave in the time domain will be completed. In particular, the dependence of the axial wave on the characteristics of the sound speed will be thoroughly studied.
2. The intensity of axial wave will be compared to the intensity of the sum of the first four to six normal modes.
3. A summary of Buldyrev and co-workers research relating to the axial wave will be completed.
4. Detailed plans for the work to be undertaken in the second year of the project will be made.

### **Second Year Plans**

As the milestone plan indicates the second year's effort will focus on the characteristics of the axial wave in a range-dependent ocean medium. The range-dependence to be considered will be deterministic and will result for such things as change in geographic location. In the future we will generalize to the stochastic problem by including the effects of the mesoscale signal and of internal waves.

Dr. Palmer will continue to work with Prof. Gregorieva through the second year of the SMTU project even though his project officially ends in March, 2004. His emphasis will continue to be the connection between the SMTU effort and the ONR sponsored experimental work on long-range propagation as well as on numerical modeling.

Modified milestone plan (taking into account the delay in funding for SMTU)

- Year 2**
- 1Q Develop the ocean model for the range-dependent problem.
  - 1Q Begin analysis of the range-dependent problem.
  - 2Q Begin numerical calculations for the range-dependent problem.
  - 2Q Attend 7<sup>th</sup> European Conference on Underwater Acoustics.
  - 3Q Begin time-domain analysis.
  - 4Q Attend San Diego ASA meeting and hold project workshop in Miami during the same trip to the US.
  - 4Q Prepare project final report.

## **WORK COMPLETED**

### **Major Accomplishments**

1. Attended and participated in the 143<sup>rd</sup> Meeting of the Acoustical Society of America, Pittsburgh, 3-7 June 2002.
2. The solutions were obtained for the homogeneous Helmholtz equation concentrated near the waveguide axis that decreases exponentially outside a strip containing the axis.
3. An integral representation of the axial wave in an arbitrary range-independent ocean was obtained.
4. A study of the dependence of the axial wave on frequency, range, and sound speed characteristics was carried out.
5. A draft summary of the experimental work on long-range, low-frequency propagation in the ocean was completed.
6. The representation for the axial wave in the time domain was obtained and its intensity in a three-dimensional, range-independent medium was computed.
7. Attended and participated in the Sixth International Conference on Theoretical and Computational Acoustics (ICTCA'2003), 11-15 August, 2003, Honolulu.
8. A project meeting was held in Miami in September 2003.

## **PUBLICATIONS AND PRESENTATIONS**

Below are listed the publications and presentations relating to the project that have been given to date:

1. N.S. Grigorieva, G.M. Fridman, and D.R. Palmer, "Investigation of near-axial interference effects for propagation in a ducted waveguide," J. Compt. Acoust. (to appear).
2. D.R. Palmer, N. S. Grigorieva, and G.M. Fridman, "Revising Buldyrev's theory of the "axial wave" after 30 years," 143<sup>rd</sup> Meeting of the Acoustical Society of America, Pittsburgh, 3-7 June, 2002.
3. N.S. Grigorieva and G.M. Fridman, "Investigation of near-axial interference effects in long-range acoustic propagation in the ocean," 143<sup>rd</sup> Meeting of the Acoustical Society of America, Pittsburgh, 3-7 June 2002.
4. N.S. Grigorieva and G.M. Fridman, "Asymptotic behavior of solutions of the Helmholtz equation concentrated near the axis of a deep-water waveguide in a range-independent medium," J. Comp. Acoust. (to appear).
5. N.S. Grigorieva and G.M. Fridman, "Axial wave in long-range propagation in a range-independent ocean," J. Comp. Acoust. (to appear).
6. N.S. Grigorieva and G.M. Fridman, "Near-axial interference effects in long-range propagation in a range-independent ocean," Sixth International Conference on Theoretical and Computational

Acoustics (ICTCA'2003), 11-15 August, 2003, Honolulu, Hawaii (to be published in the conference proceedings).

7. N.G. Grigorieva, G.M. Fridman, and D.R. Palmer, "Investigation of near-axial interference effects for propagation in a ducted waveguide," ICTCA'2003 Memorial Issue dedicated to Professor Frederick D. Tappert (in review).

8. N.S. Grigorieva and G.M. Fridman, "Dependence of the axial wave on range, frequency, and sound-speed profile properties in a range-independent ocean," J. Comp. Acoust. (in review).

9. N.S. Grigorieva and G.M. Fridman, "Time-domain analysis of near-axial interference effects for long-range acoustic transmissions in the ocean," Report for the 7<sup>th</sup> European Conference on Underwater Acoustics (ECUA'2004), 5-8 July 2004, Delft, the Netherlands (abs).

10. N.S. Grigorieva and G.M. Fridman, "Long-range acoustic propagation in the frequency and time domains," AOML, 16 September 2003.